IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of:

Inventor	:	Sung-Koog Oh et al.	Examiner	:	Sung H. Pak
Serial No.	:	10/754,027	Group Art Unit	:	2874
Filed	:	January 8, 2004			
Title	:	PHOTONIC CRYSTAL FIBER PREFORM AND PHOTONIC CRYSTAL FIBER MANUFACTURED USING THE SAME			

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Alexandria, VA. 22313-1450

LETTER

Sir:

Applicant calls to the attention of the Patent and Trademark Office a Search Report issued abroad in reference to a corresponding foreign application. A copy of the Search Report dated October 20, 2006, is attached.

The enclosed Search Report is not intended to be construed as an admission by the Applicant that any of the references cited therein is material.

Respectfully submitted,
CHA & REITER

By: Steve S. Cha
Attorney for Applicant

Date: March 7, 2007

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I hereby certify that this correspondence is being deposited with the United States Postal Service as first class mail in an envelope addressed to MAIL STOP ISSUE FEE, P.O. BOX 1450, ALEXANDRIA, VA. on March 7, 2007.

Steve Cha, Reg. No. 44,069
(Name of Registered Rep.)

(Signature and Date)

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Date	
20-10-2006	

Reference	Application No./Patent No.
S101314EP	04007935.2 - 1524
Applicant/Proprietor	
SAMSUNG ELECTRONICS CO., LTD.	

BRIEF COMMUNICATION

Subject:

- [x] Your letter of 25-09-2006
- [ ] Our telephone conversation of
- [ ] Communication of
- [ ]

Enclosure(s):

- [ ] Letter from the proprietor of the patent of
- [ ] Letter from the opponent of
- [ ] Copy(copies)
- [x] Communication: see attached Form 2916

Please take note.

For the Examining Divison

Europäisches Patentamt • European Patent Office • Office européen des brevets

- [ ] **Registered letter**

EPO Form 2911 05.02 20.10.06

VC23117

1. To assist the applicant in preparing for the oral proceedings scheduled for 24.10.2006 the following provisional non-binding opinion is transmitted based on the amendments received with the applicant's letter dated 25.09.2006.

2. The following document is introduced into the procedure and is annexed to this brief communication:

   D9: "Fully dispersion controlled triangular-core nonlinear photonic crystal fiber", K. P. Hansen et al., OFC 2003 - Optical Fiber Communication Conference and Exhibition - Optical Fiber Communication Conference and Exhibition, Postdeadline Papers, PD2 - 1-3 vol.3, (23-28 March 2003).

3. Claims 1 and 13 introduce subject-matter contrary to Art. 123(2) EPC in view of the new wording " at least controlled in the center" which infers that the index of refraction is only controlled in the center whereas in the original disclosure the index is described as gradually decreasing "from the center.......to the outer circumference".

   Furthermore according to the original disclosure, the index of refraction of the precise center (axis) of the fiber or fiber preform is not controlled (no member is positioned at this point). Thus such an interpretation of "<u>in</u> the center" also leads to an Art. 123(2) EPC objection.

4. The applicant apparently argues in his letter that according to the invention the refractive index is controlled in the centre and this is equivalent to the core. The division can see no teaching in the original disclosure of controlling the refractive index in the core by arranging longitudinal members. The terms centre and core are not equivalent.

5. D3 destroys the novelty of claims 1 and 13 since the center includes members having different indices of refraction (col. 5, l. 50-52 "extended core 54 includes core 44 and moat 50").

6. Since also the term "center" does not give an indication as to its extent, a region corresponding to the centers in D1, D2 and D4 can also be understood to include a plurality of members (the center can be set arbitrarily). Thus since a filled void in D1 can be interpreted to be a longitudinal member, D1 is prejudicial to the novelty

of claims 1 and 13, and the subject-matter of these claims lacks an inventive step in view of D2 and independently in view of D4.

7. Since D9 discloses a core having an up-doped center element surrounded by three down-doped regions i.e. using different members to control the index of refraction in the central core (since the doping determines the refractive index) and a rod-shaped substrate is implicitly disclosed, glass is a synonym for silica in optical fiber technology and the term "embedded" implies longitudinal members are used, the subject-matter of claims 1 and 13 appears to lack novelty in view of D9.

8. It is unclear (Art. 84 EPC) in claims 1 and 13 whether the feature "in the center" means the central on-axis position of the fiber or a region including this position.

1/1 - (C) INSPEC / IEE
COPY- 2004 IEE
AN - 7971086
DT - Conference Paper
PD - 2003-00-00
TI - Fully dispersion controlled triangular-core nonlinear photonic crystal fiber
AU - Hansen K P; Folkenberg J R; Peucheret C; Bjarklev A
CONF- OFC 2003 - Optical Fiber Communication Conference and Exhibition. Postdeadline Papers
- 23-28 March 2003
- Atlanta, GA, USA
PUB - Optical Fiber Communications Conference (OFC). (Trends in Optics and Photonics Series Vol.86) Postdeadline Papers (IEEE Cat. No.03CH37403)
- 2003
- Opt. Soc. America
- Washington, DC, USA
VOL - 3
PG - PD2 - 1-3 vol.3
PCC - A4270Q; A7820P; A4281D; A4265; B4125; B4340; B6260
IW - nonlinear optics; optical fibre communication; optical fibre dispersion; photonic crystals
AW - dispersion controlled triangular-core; nonlinear photonic crystal fiber; dispersion level; broad wavelength range; nonlinear coefficient
AB - We demonstrate the first nonlinear fiber where both dispersion level and slope can be fully controlled in a broad wavelength range while maintaining low loss and a high nonlinear coefficient. Lowest slope obtained is 1.10<-3>ps/(km.nm<2>)

Fully Dispersion Controlled Triangular-Core Nonlinear Photonic Crystal Fiber

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Abstract: We demonstrate the first nonlinear fiber where both dispersion level and slope can be fully controlled in a broad wavelength range while maintaining low loss and a high nonlinear coefficient. Lowest slope obtained is $1\cdot10^{-3}$ps/(km·nm^2).

OCIS codes: (060.4370) Nonlinear optics, fibers; (060.2310) Fiber optics

1. Introduction

Nonlinear photonic crystal fibers (PCFs) were among the first fiber types to demonstrate the advantages of the PCF technology [1] and they have since then proved their worth in numerous applications. With the introduction of the nonlinear telecommunication PCF [2,3] the high index contrast and flexibility of the PCF technology was utilized to create a fiber with a very high nonlinear coefficient and zero dispersion at 1.55 μm. Although showing superior performance in applications like all-optical demultiplexing [4,5], the high dispersion slope of more than $-2\cdot10^{-1}$ ps/(km·nm^2) limits the useful spectral bandwidth of the fiber. The slope can be significantly reduced by lowering the ratio between hole-size, d, and pitch, Λ, but at the cost of a considerable increase in both effective area and confinement loss [6]. Consequently, dispersion-flattened fibers with a d/Λ on the order of 0.25-0.3 will exhibit a nonlinear coefficient 5-10 times lower than a fiber with a slope of $-2\cdot10^{-1}$ ps/(km·nm^2).

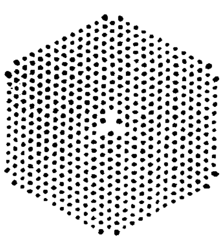
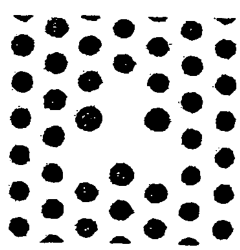
PCFs with very low and flat dispersion can also be realized by reducing the hole-size to sub-μm in the inner ring around the core. However, this poses significant fabrication challenges and such designs have only been treated theoretically [7].

The dispersion slope of standard nonlinear step-index fibers is on the order of $2\cdot10^{-2}$ ps/(km·nm^2). Reduction of the slope can be obtained by introducing a depressed cladding region around the core and fibers with a slope as low as $1.3\cdot10^{-2}$ ps/(km·nm^2) have been demonstrated [8]. The limitation in this method of slope reduction is the index contrast between the core and the depressed cladding set by the obtainable doping levels.

In this paper we demonstrate, for the first time, a new type of nonlinear PCF that features full control of both dispersion level and dispersion slope while maintaining low loss, a high nonlinear coefficient and simple fabrication.

2. Fiber Design and Characterization

The fabricated fibers feature a three-fold symmetric hybrid core region comprising an up-doped center element surrounded by three down-doped regions (doped glass provided by Shin-Etsu Chemical Co., Ltd. Japan) embedded in a standard triangular cladding structure (see Figure 1 A and B). Due to the shape of the core, the near field appears three fold symmetric (see Figure 1 C).


(A)

(B)

(C)

Figure 1 (A) Microscope picture of the microstructured region of the fiber. (B) The triangular core region comprises an up-doped center element surrounded by three down-doped regions and three holes. (C) Contour plot of near field measured at 1.55 μm.

The shown contour plot of the near-field has a logarithmic scale and most of the power is located in the central Gaussian-like part. Consequently, coupling to standard step-index fibers is very efficient and the fiber can be spliced to step index fibers with a loss of 0.25 dB.
The hybrid core adds additional flexibility in the design of the dispersion compared to the well-known single core triangular cladding PCF. By varying the pitch and hole-size, it is possible to alter the balance between the negative waveguide dispersion contribution from the holes and the positive contribution from the down-doped regions, respectively. The sum of waveguide and material dispersion in the fiber can thereby be altered to obtain the desired dispersion profile (see insert in figure 2). The dispersion can be tuned to almost any combination of dispersion level and dispersion slope in the range 1400-1700 nm, including zero dispersion and flat slope. The low slope can be maintained in a large wavelength range and it is possible to keep the dispersion variation within 1ps/(km·nm) over more than 200 nm. Nonlinear fibers with such a dispersion profile can pave the way for a range of new broadband tunable devices like tunable optical parametric amplifiers, wavelength converters, regenerators and all-optical demultiplexers - devices which, until now, have been limited to operation close to 1.55 μm.
The calculations shown in Figure 2 illustrate how the dispersion can be locked to zero at a single wavelength (in this case 1.55μm) while the slope can be freely tuned.
To illustrate the flexibility of the design, we have fabricated a range of fibers with different combinations of pitch and hole-size. All fibers are drawn in lengths of 500 m and exhibit a structural uniformity (pitch and hole-size) better than 1% along the fiber. In Figure 3 are shown measured dispersion curves for a range of fibers drawn with similar d/Λ of ~0.5 and increasing pitch in the range 1.34 – 1.47 μm. The pitch adjustment allows choosing the dispersion level at a given wavelength or tuning the zero-dispersion wavelength.

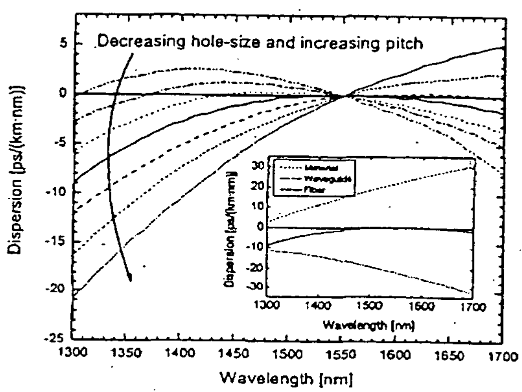


Figure 2 The dispersion slope can be tuned while maintaining a fixed zero-dispersion wavelength (simulated data). Insert shows the balance between material and waveguide dispersion for a fiber with zero dispersion slope at 1.55 μm.

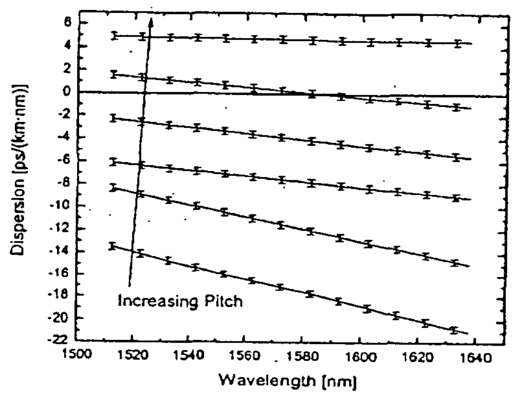


Figure 3 Measured dispersion of a range of fibers with d/Λ=0.5 and pitch in the range 1.34 – 1.47 μm. The choice of pitch determines the dispersion level or zero-dispersion wavelength.

Slope tuning can be obtained by changing the hole-size as illustrated in Figure 4 where the measured dispersion of four different fabricated fibers is shown. The dispersion at 1580 nm has been fixed at approximately -1 ps/(km·nm) and the slope is tuned from $-3\cdot10^{-2}$ to $+1\cdot10^{-2}$ ps/(km·nm^2) by choosing holes in the range 0.47 – 0.50 μm and a pitch of 1.48 – 1.51 μm. Fiber 3 has a slope of less than $1\cdot10^{-3}$ ps/(km·nm^2), which is, to the best of our knowledge, more than one order of magnitude lower than the lowest slope ever reported for a nonlinear fiber. A broader dispersion curve of an equivalent fiber is shown in Figure 5. The dispersion variation is within 1 ps/km/nm in the range 1465-1655 nm..

The nonlinear coefficient of the flat slope fiber is approximately 11.2 (W·km)$^{-1}$ measured by analyzing the self-phase modulation induced nonlinear phase shift from a dual frequency continuous wave source [9]. The nonlinear coefficient scales linearly with the slope of the fibers (fibers with negative slope yields higher nonlinear coefficient) and a fiber with a negative slope of $-2\cdot10^{-2}$ ps/(km·nm^2) has a nonlinear coefficient of approximately 12.5 (W·km)$^{-1}$.

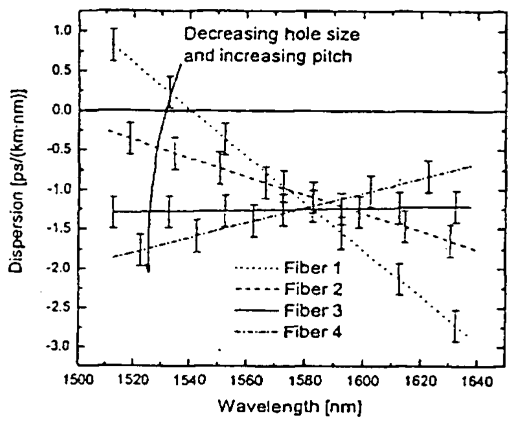


Figure 4 Measured dispersion of four fibers with hole-sizes in the range 0.47 – 0.50 μm and pitch of 1.48 – 1.51 μm. The choice of structural parameters enables tuning of the slope from $-3\cdot10^{-2}$ to $+1\cdot10^{-2}$ ps/(km·nm^2).

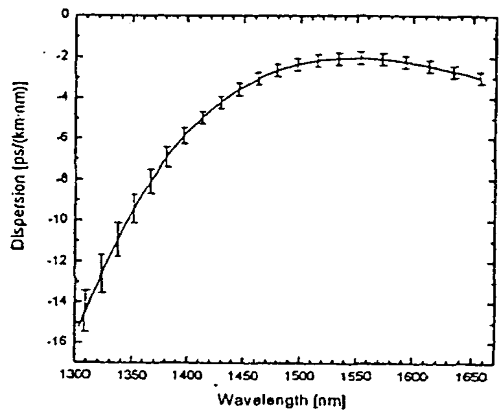


Figure 5 Dispersion curve of an ultra slope reduced fiber. The dispersion variation is within 1 ps/(km·nm) in the range 1465-1655 nm. The fiber is equivalent in structure to Fiber 3 in Figure 4.

The attenuation of the fibers is in the range 12.5 to 9.9 dB/km at 1.55 μm and there is no sign of confinement or bending loss at this wavelength.
As the structure of the fiber features three-fold symmetry, there is no inherent birefringence to the design. In practice, however, the fibers exhibit a birefringence on the order of 10^{-5} - 10^{-4} (measured by the fixed-analyzer method). The birefringence is believed to arise from asymmetry in the doped regions and stress, induced by the difference in thermal expansion coefficients and viscosity of the core elements.

3. Conclusion
We have demonstrated a novel type of nonlinear photonic crystal fiber with a triangular hybrid core region. By tuning the hole-size and pitch we have demonstrated how the dispersion of the fiber can be designed, and fibers with negative, positive as well as near zero dispersion slope have been fabricated. The lowest slope obtained is $1\cdot10^{-3}$ ps/(km·nm^2) which is one order of magnitude lower than conventional slope reduced nonlinear fibers. This ultra low slope fiber has a nonlinear coefficient of 11.2 (W·km)$^{-1}$. The fibers exhibit a loss down to 9.9 dB/km at 1.55 μm and can be spliced to standard single-mode step-index fibers with a loss of only 0.25 dB. The structural uniformity in the length direction is better than 1 % over 500m.

4. References

[1] N.G.R.Broderick, T.M.Monro, P.J.Bennett, and D.J.Richardson *"Nonlinearity in holy optical fibers: measurement and future opportunities"* Optics Letters, 24 (20), 1395-1397 (1999).

[2] Kim P.Hansen, Jacob Riis Jensen, Christian Jacobsen, Harald R.Simonsen, Jes Broeng, Peter M.W.Skovgaard, Anders Petersson, and Anders Bjarklev *"Highly Nonlinear Photonic Crystal Fiber with Zero-Dispersion at 1.55 μm"* OFC 02 post deadline, (2002).

[3] Kim P.Hansen, Jacob R.Folkenberg, Anders Petersson, and Anders Bjarklev *"Properties of Nonlinear Photonic Crystal Fibers for Telecommunication Applications"* Conference on Optical Fiber Communication, OFC, (2003).

[4] K.S.Berg, L.Oxenløwe, A.Siahlo, A.Tersigni, A.T.Clausen, C.Peucheret, P.Jeppesen, K.P.Hansen, and J.R.Jensen *"80 Gb/s transmission over 80 km and demultiplexing using a highly nonlinear photonic crystal fibre"* ECOC 2002, (2002).

[5] L.K.Oxenløwe, A.Siahlo, K.S.Berg, A.Tersigni, C.Peucheret, A.T.Clausen, K.P.Hansen, and J.R.Jensen *"A photonic crystal fibre used as a 160 to 10 Gb/s demultiplexer"* Post Deadline OECC, (2002).

[6] W.H.Reeves, J.C.Knight, and P.St.J.Russel *"Demonstration of ultra-flattened dispersion in photonic crystal fibers"* Optics Express, 10 (14), 609-613 (2002).

[7] A.Ferrando, E.Silvestre, J.J.Miret, and P.Andrés *"Nearly zero ultraflattened dispersion in photonic crystal fibers"* Optics Letters, 25 (11), 790-792 (2000).

[8] Jiro Hiroshi, Naomi Kumano, Kazunori Mukasa, Ryuichi Sugizaki, Ryo Miyabe, Shun-ichi Matsushita, Hideaki Tobioka, Shu Namiki, and Takeshi Yagi *"Dispersion slope controlled HNL-DSF with high gamma of 25 W-1km-1 and band conversion experiments using this fiber"* ECOC 2002, (2002).

[9] A.Boskovic, S.V.Chernikov, J.R.Taylor, Lars Grüner-Nielsen, and O.A.Levring *"Direct continuous-wave measurement of n2 in various types of telecommunication fibers at 1.55 μm"* Optics Letters, 21 (24), 1966-1968 (1996).